NEW ASPECTS IN NUCLEON-NUCLEUS COLLISIONS AND EAS PROPERTIES AROUND 10^6 GeV

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1. Introduction

At energies higher than 2.10^5 GeV, we have very few information on detailed properties of nucleon-nucleon collision ; the rare elements are coming from "jets", and, as non direct improvements from γ-ray families. The results exhibit some conflicting features, or, at least, very large fluctuations like copious production of γ-rays in opposition to Centauro-like events, sometimes suggest that phase transition to quark gluon plasma occurs in nucleus-nucleus collisions and even in nucleon-nucleus collision (1) (2). The multicluster phenomenological model (MPM) is here extrapolated for EAS simulation up to 5.10^6 GeV to put in evidence some significant deviation between experimental data and prediction.

2. Extrapolation of short range order picture, nucleus-nucleus collision

The emission of small clusters from nucleon-nucleon collision is taken following (3) assuming always that the width of the plateau of rapidity is rising with Ln s (and also the height); the secondary particles are generated by decay of those clusters like in (4) but the truncated Poissonian distribution has been replaced by a Gaussian distribution. The width of this Gaussian has also been parametrized versus Ln s at ISR and $\bar{p}$-p energy and extrapolated in continuity of HE 4.1-9. The extension to p-air collision is also not different.

The most convenient was in this last case to generate directly the clusters from an inclined plateau, the rapidity of a cluster in CMS y_c being obtained from

$$\int_{-y_o}^{y_c} R(y)\,dy = \xi \int_{-y_o}^{y_o} R(y)\,dy$$

(ξ simple random number) and decay those clusters like for nucleon-nucleon collision in center of mass system. About KNO violation and asymptotic limit for fluctuations of multiplicity, as well as correlation between $< p_t >$ and central rapidity density we assume strict continuity with the previous description at energies higher than 2.10^5 GeV, as well as for proportion of different species $K^{\pm}$, p,$\bar{p}$ (taken as in ref. (1) of HE 4.1-9).

Nethertheless, we introduced here one variant in MPM concerning the production of secondary η mesons : herealso, a Ln s increase has been taken from the invariant mass distribution of the two-photon sample in UA2 experiment and the rate previously estimated in ISR. In this version, about half of the photons produced in a collision of 10^6 GeV are coming from η mesons (fig. 1).

A typical characteristic of the multicluster phenomenological model is the constant decrease of total inelasticity $< K >$ for nucleon-nucleon collision (underlined in HE 4.1-9) and consequently for p-air collision (fig. 1), estimated by summation of the energy carried by secondaries in Laboratory system.

The extension to nucleus-nucleus collision follows ref.(6) in HE 4.1-9 : the plateau of rapidity is transformed like for p-nucleus, assuming an increase of multiplicity in collision of nuclei A and B

$$R\left(\frac{AB}{pp}\right) \sim \tfrac{1}{2} < \nu_A > + < \nu_B > = \tfrac{1}{2} P$$

B being the air constituent target nucleus.(ν is defined as for p-nucleus and P is the number of participating nucleons). In the EAS Monte-Carlo simulation, we have treated separately the contribution coming directly from the participating nucleons and the contribution governed by the behaviour of the "spectators".

3. Comparison with experimental data

We obtain with 5 GeV muon in Tian-Shan a better agreement than with models previously used (fig.2, 4.1-9) ; muon content after 10^6 GeV deviates from MPM, but if we consider the version assuming η meson production the agreement is restored up to 5.10^6 GeV. This can be explained by the larger number of γ's produced in the η channels decay with lower individual energies than in π^o decay.The muon of 220 GeV are also in agreement with KGF data (fig. 3 HE 4.1-9) and Moscow data for muons of the same energy (5); the flattening in the experiment after $N_e = 10^6$ is up to now not confirmed in Moscow and it could be an effect of the small statistics. Very good agreement is also obtained at Tian-Shan level for high energy hadrons, and also for the $< E_H r_H >$ factor (fig. 2). Up to now, $< E_H r_H >$ was decreasing with energy with a majority of models but in one case, including decrease of $< K >$ versus rising s (6). We note that in MPM this circumstance is also the cause of the large number of energetic hadrons surviving at Tian-Shan altitude.

Satisfactory situation appears also for maximum depth T_{max} versus energy (fig. 3); for instance, T_{max} near 10^6 GeV is measured near 520 g.cm^{-2} by Cerenkow method (5) when MPM gives 550 g.cm^{-2} for proton. We observe that the maximum depth from Cerenkow measurements is located at deeper altitude than in previous experiments with lower number of detectors and smaller resolution. If η meson production is assumed, the maximum depth decreases by about 35g.cm^{-2}. Furthermore, very good agreement is obtained with the most recent data on T_{max} measurements (7).

4. Conclusion

If we consider the good agreement obtained with age parameter data in Akeno (HE 4.3-13), we can conclude that the multicluster phenomenological model gives an acceptable description of EAS data and can be extended at least at one decade higher than the $\bar{p}$-p energy. If we include η meson production, it can be even accepted at energies near 10^7 GeV. A rise of rapidity plateau in Ln s (simultaneously in width and height) appears sufficient and

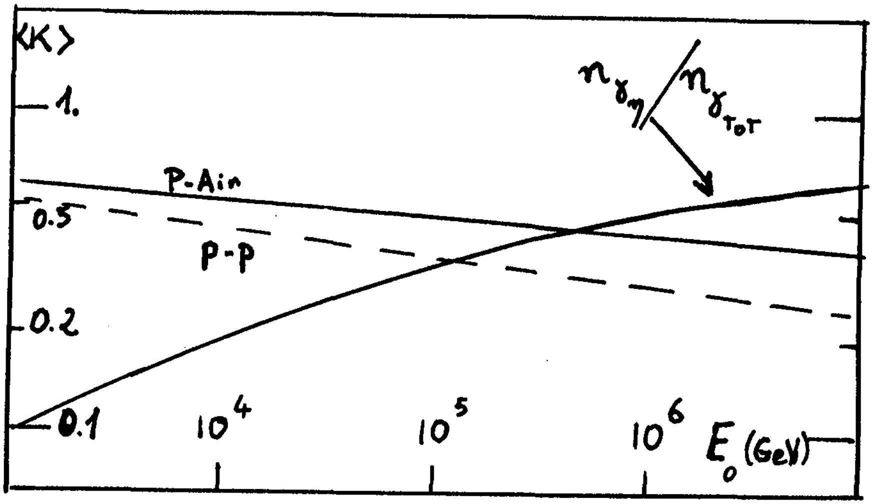
⟨K⟩
1.
0.5
0.2
0.1
P-Air
P-P
$n_{\gamma_\eta} / n_{\gamma_{TOT}}$
10^4
10^5
10^6
E_0 (GeV)

Fig. 1

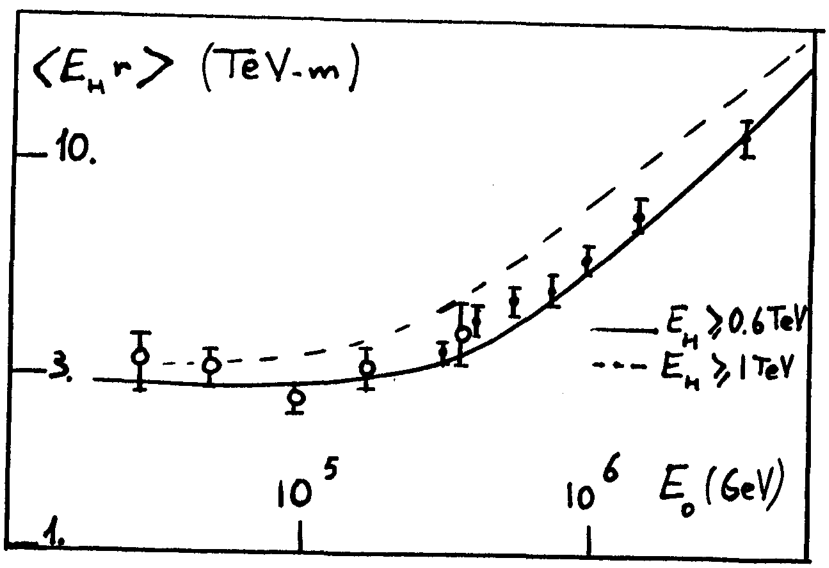
$\langle E_H r \rangle$ (TeV-m)
10.
3.
1.
10^5
10^6
E_0 (GeV)
$E_H \geqslant 0.6$ TeV
$E_H \geqslant 1$ TeV

Fig. 2

differently with previous models we don't need any exotic change in composition or in multiplicity to explain in this kinematical range the experimental data. At least, it appears no necessity of any enhancement of heavy nuclei in primary component. A very large fraction of the rapidity plateau is compatible, and, may be, only in the central region we cannot exclude a more important rise of rapidity density.

References

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∇ Khristiansen, 85

Other points from Nagano, R.P. 83.

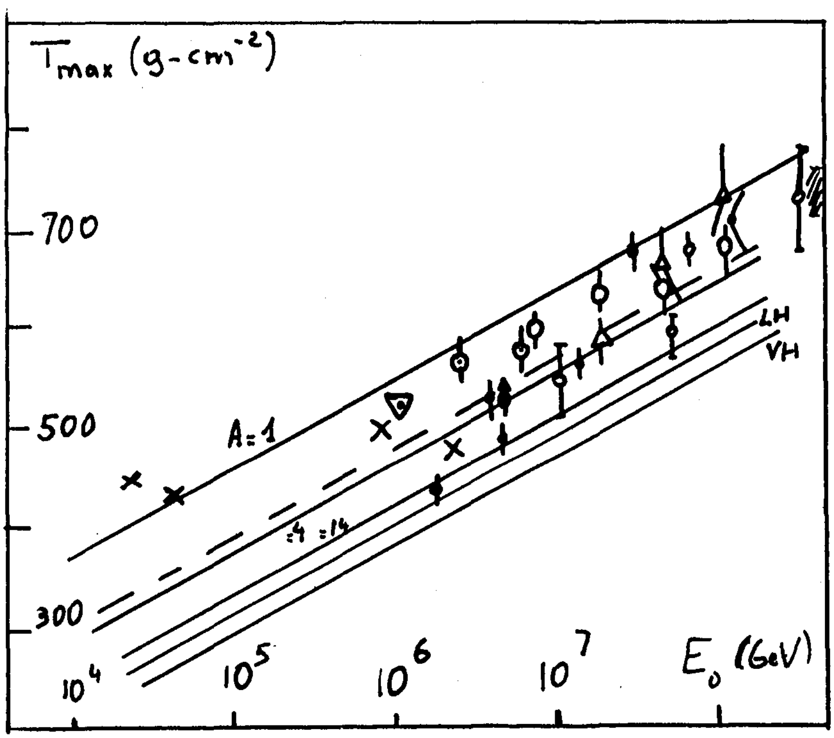

Fig. 3